PROSPECTS FOR GLOBAL CORRELATION OF PERMIAN SEQUENCES

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Three outstanding problems of Permian correlation are illustrated in this paper by means of the selected tie points. Among them, defining the corresponding level of the base of the Guadalupian in the Tethyan areas is particularly pressing since we need a sound basis for establishing its Global Stratotype Section and Point (GSSP). Coincident occurrence of leading species of conodont zones in South China and SW USA indicates that the Kubergandinian Stage of the Tethyan areas is unlikely to be equivalent to the Roadian Stage of the global standard. Longstanding interpretation has suggested that Lopingian marine deposits are essentially absent over Pangean shelves. However, whether it is a depositional gap of more than ten Ma or an evolutionary stasis of marine faunas remains uncertain. A north–south correlation of Permian chronostratigraphic successions is especially problematical. The discrepancy between various correlation of magnetostratigraphic successions in Australia, North China and the Urals prompts an alternative interpretation for the age of the supposed Ufimian normal polar zones in Eastern Australia, that is, the Late Guadalupian or the Early Tatarian.

RECENTLY, an integrated chronostratigraphic scheme for the Permian system was approved by the Permian Subcommission, International Commission on Stratigraphy (Jin et al. 1997). The scheme integrates the Cisuralian Series of the Lower Permian from the traditional standard sections in the Urals, the Guadalupian Series of SW USA and the Lopingian Series of South China, because the Upper Permian of the classic sequence is composed of facies not suitable for defining the boundary stratotypes. This scheme will not only serve as a working template for the Subcommission in defining the Global Stratotype Section and Points (GSSPs) for intra-systemic boundaries following the concept and procedures of modern stratigraphy, but also as a catalyst for developing a more reliable global correlation of the Permian. An attempt to erect a correlation between the proposed standard and other Permian successions is a common desire for Permian stratigraphers since a reliable time framework for better understanding the geological history cannot be provided without precise correlation. It is a particularly urgent task for the correlation of post-Artinskian successions, which is far from precise, because of the strong biogeographic differentiation. On the other hand potentiality of correlation is a basic requirement of an acceptable stratigraphic boundary level. While the correlation used this scheme as a standard, the correlation, in turn, served as an invaluable basis for improvement of the scheme, in an extremely helpful process of leapfrogging.

The purpose of this paper is to explore reliable and practicable means for establishing a sound correlation and to identify the most prominent problems involved at present. Emphasis is on correlation between the Tethyan Kubergandinian Stage and the global standard Roadian stage, correlation of Lopingian deposits in Pangean shelf areas, and between the Permian in Australia and in the Urals in terms of physical stratigraphic evidence including isotopic age, magneto- and sequence stratigraphic data.

HISTORICAL REVIEW

Since Waterhouse (1976) contributed a thorough survey of the world correlation of marine Permian with his composite scheme as the standard, much clarification has been done on the intercontinental correlation of the Permian. The most prominent changes in correlation between Permian regional sequences during the last two decades include these points:

The Tatarian in the Urals has long been considered as an international standard for the latest Permian. The terrestrial nature of the standard Tatarian makes it very difficult to correlate with marine sequences. Conventionally, it is an equivalent of the Lopingian or the Dzhulfian in the Tethyan areas. Occurrence of the Illawarra Reversal in the lower portion of the Tatarian in its type section indicates that this stage extends well below the Capitanian Stage (Menning et al. 1986).

The Kungurian in the Urals has been regarded as a coeval part of the lower Maokouan in South China or the Roadian in SW USA by Ustritsky (1971) and Waterhouse (1976), and that of the Chihsian of South China or the Leonardian of SW USA by Grant & Cooper (1973) and Furnish (1973). It has been documented as an equivalent of the Chihsian Subseries of South China and the Cathedralian in SW USA as each is defined by the *Neostreptognathodus pnevi–N. exculptus* conodont zone at the base (Jin et al. 1994).

Following the establishment of the Guadalupian–Lopingian boundary sequence in South China, quite a few regional units that have been proposed as the global standard for a pre-Dzhulfian and post-Guadalupian interval were clarified in age. Among them, the Punjabian Stage consisting of the Chhidruan and the Kalabaghian Substage (Waterhouse 1976), was regarded as a unit below the Lopingian Series by brachiopod experts (Grant & Cooper 1973; Waterhouse 1976; etc.), but essentially as an equivalent of the Lopingian Series by ammonoid experts (Furnish 1973). Data from the study of foraminifers (The Pakistan–Japanese Research Group 1985) and conodonts (Wardlaw & Pogue 1995) from its type sections support the views of Furnish (1973). The Abadehian Stage (Taraz 1974) has been shown to be of latest Guadalupian age by having *Yabeina* in its upper part (Baghbani 1991), and further confirmed by having *Clarkina dukouensis* of the earliest Wuchiapingian from the overlying the Hambast Formation (Golshani et al. 1996).

From the foregoing review, it would appear that the responsibility of correlation for Permian successions has depended over the last two decades mainly on the interpreted evolutionary succession of regionally limited ammonoid, brachiopod and fusulinid faunas. Since then, prime value has shifted to the zonation of other fossil groups such as conodonts, radiolarians and palymorphs, and to physical stratigraphic evidence as well.

THE FIRST ORDER OF TIE POINTS FOR GLOBAL PERMIAN CORRELATION

Stratigraphic evidence that can serve as a reliable tie in global correlation is limited and particularly so for biostratigraphic zones above the Artinskian Stage. Lack of directly worldwide applicable biostratigraphic zonation of Permian successions implies the necessity to resort to other means, such as isotopic dating and the magnetostratigraphy to establish a reliable chronostratigraphic correlation between the Permian of various palaeobiogeographic realms.

Biostratigraphic zones. The refined zonation of Permian conodonts achieved in recent years enables us to link up the type sections of the four divisions as precise ties between them in the Palaeoequatorial Realms. The superposition between the Guadalupian Series in SW USA and the Lopingian Series in South China can be confirmed by sharing a succession from the *Jinogondolella altudaensis* Zone to *Clarkina postbitteri*. The first occurrence of *J. nankingensis* can serve as a mark to correlate the basal level of the Guadalupian Series of SW USA and that in the Tethyan areas. The *Neostreptognathodus pnevi–exculptus* Zone, which has been recognised in Urals, South China and SW USA, makes a confident connection between the base of the Kungurian sequences of these areas. From the conodont succession, it will be normally easier to correlate secondarily into the successions of the fusulinids, ammonoids, palynomorphs and other fossil groups, which are critically important for correlation as well.

Magnetostratigraphic zones and radiometric age. The improved biostratigraphic zonation and the magnetostratigraphic and radiochronological time scale will provide a framework to link all regions both inside and beyond the Palaeoequatorial realms. At present, emphasis of these studies is laid on locating the Illawarra Reversal and dating the volcanic beds with precise biostratigraphic control. According to Dr Haller and his colleagues, the Illawarra Reversal (IR) occurs in the upper part of the Maokou Formation in South China and the Lower part of the Wargal Formation in Salt Range, which are corresponding with the *Neoschwagerina margaritae* Zone and the *Jinogondolella aserrata* Zone of the Wordian Stage. With regard to the magnetostratigraphic zonation, the Permian beds of the Carboniferous–Permian Reversed Megazone (CPRM) may be grouped into a normal zone in the basal part and a reversal zone for the rest part, and those of the Permian–Triassic Mixed Megazone (PTMM), into two normal and two reversal zones. For the isotopic ages listed in Fig. 1 we only include those from the type regions of respective series, the Cisuralian in the Urals, the Capitanian in the Guadalupian, and the Lopingian in South China and thus, have not been statistically 'normalised'.

Major sequence stratigraphic boundaries. Ross & Ross (1987), based on data from North America and Russia, referred the Permian sequences to a single second order cycle, the Transpecos Supercycle, consisting of about twenty-three third order

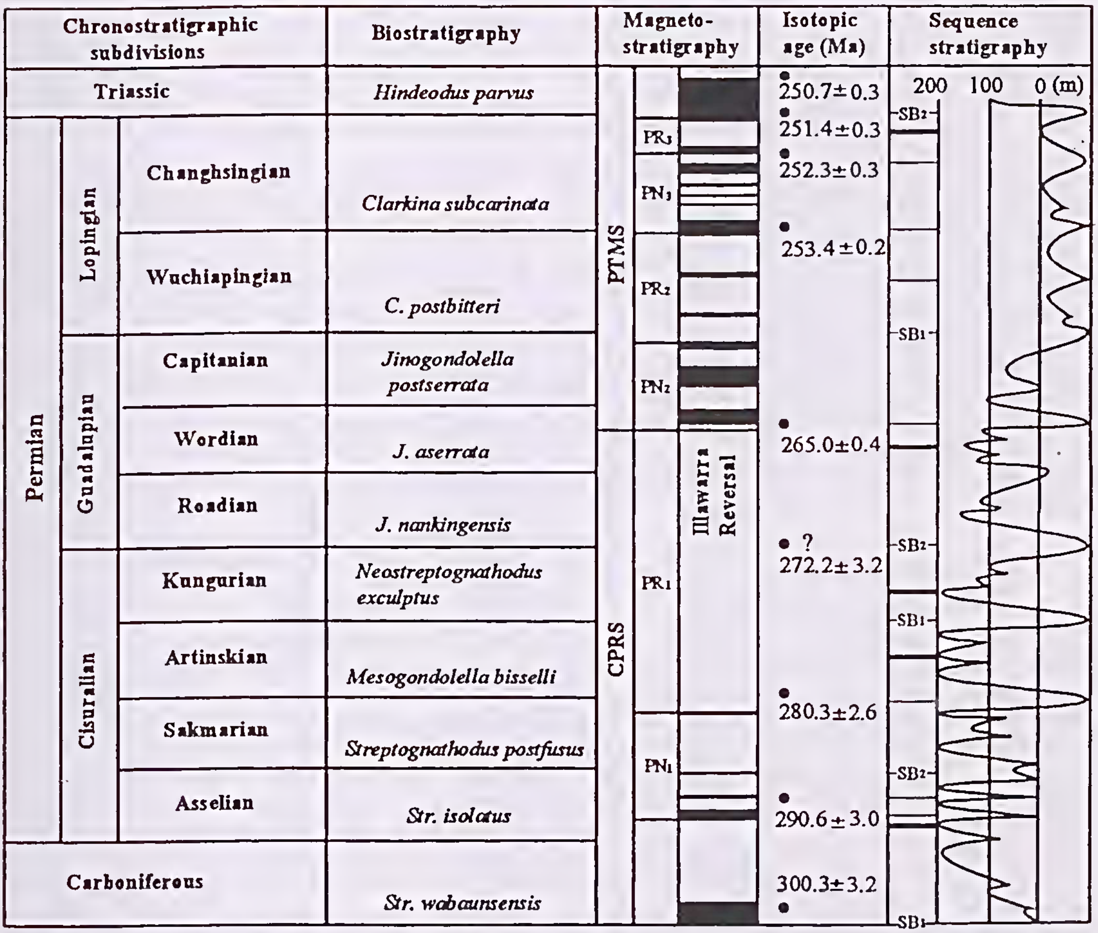

Fig. 1. The first order of tie points for global Permian correlation. Names of chronostratigraphic units, the basal conodont zone of each unit, magnetostratigraphic sequence and isotopic age are adopted from Jin et al. (1997) and the sea level change curves from Ross & Ross (1994), with modification. The stratigraphic sequences integrated the data from the type area of each series: SB1, SB2, type 1 and type 2 sequence boundary of the second order; solid bar, the level of maximum sea flooding; fine bar, sequence boundary of the third order.

cycles. The eustatic curve drawn out by Holser & Magaritz (1987) based on an analysis of 68 major depositional basins shows three major regressions respectively in the Late Artinskian, end-Guadalupian and end-Tatarian. The Permian sequence of South China comprises two major regressions, which reached their acme respectively at the end of the Artinskian (*Pamirina* zone), and the end of the Guadalupian (*J. granti* Zone). The unconformities caused by these regressions are significantly greater than others, and therefore, can be regarded as anchor points of correlation. In addition, the prominent erosional contact between the Leonardian and the Guadalupian beds represents a major type 1 sequence boundary, above which were deposited carbonate megabreccias and shale of the Cutoff Formation in SW USA. This boundary surface is correlative to that between the Chihsian and the Maokouan in South China, and the Ufimian continental deposits in the Urals (Ross 1995).

Chemostratigraphic signals. A survey on the general trend for the change of isotopic values of sulfate, strontium and carbon from the Carboniferous to the Jurassic (Scholle 1995) shows that superior chemostratigraphic signals have a great potential in the international correlation. Two high peaks of carbon isotopic excursion are distinguished, which appear respectively in the Wuchiapingian Stage and the Early Kungurian Stage, and coincide respectively with the dramatic declines of strontium values, and the minimum value of strontium and sulfur. Recently, a rapid declination of strontium values was found at the continental sequence probably corresponding with the Wuchiapingian, and a sudden drop of organic carbon isotopic value occurs around the P–T boundary in Australia (Morante 1996). A profile integrating the data of carbon isotopic values from a few sections of South China indicates again the significant changes, those are two low values respectively around the Guadalupian–Lopingian and the P–T boundaries, the peaks around the early Kungurian, the Wordian and the Wuchiapingian Stage.

THE ROADIAN STAGE *VERSUS* THE KUBERGANDINIAN STAGE

At present, improving the correlation of the Permian within the Palaeoequatorial realms is particularly pressing since we should integrate the Kungurian sequences in SW USA and Tethys into a standard succession that would be internationally acceptable. Moreover, the corresponding level of the base of the Guadalupian in Tethyan areas has not been determined.

The Roadian has long been referred to as an equivalent of the Kubergandinian of the Tethyan areas, because the Roadian ammonoid fauna is said to be found from the *Cancellina* Zone in Pamir (Bogoslovskaya et al. 1994). Based on a fact that the lowest level of *J. nankingensis* presently known is the *Praesumatrina neoschwagerinoides* Zone in South China, however, this stage is correlated to the Murgabian Stage, and thus, is referred as a stage above the Kubergadinian Stage in the Permian scheme proposed by Jin et al. (1994).

The Roadian Stage of the Guadalupian Series is proposed to be indicated by the first appearance of *Jinogondolella nankingensis* within an evolutionary cline from *Mesogondolella idahoensis* to *J. nankingensis* in the El Centro Member of the Cutoff Formation (Glenister et al. 1992). Proposed initial boundaries of the Wordian and the Capitanian Stage are respectively indicated by the first appearance of *J. aserrata* within the Gateway Limestone Member of the Brushy Canyon Formation and that of *J. postserrata* within the Pinery Member of the Bell Canyon Formation. Beneath the basal Guadalupian are the Hessian (Ross 1986) and the Cathedralian Stages (Ross & Ross 1987). Five conodont zones are recognised in their type area. The *Mesogondolella gujiaoensis–N. exculptus* Zone near the base of the Hessian contains *N. pnevi* and other conodonts that should permit precise correlation to *N. pnevi* Zone in the Urals.

The Kubergandinian Stage with reference section along the right bank of the Kubergandinian River in southeastern Pamir, was redefined by Leven in 1979 to include the *Armenia* and *Cancellina* Genozone, when he named the underlying Bolorian Stage to include the *Misellina* Genozone with the stratotype located along the divides between the Tschalidala, Kundara and Zidadara rivers in southwestern Darvase. Their equivalents in SW USA cannot be determined since the indicative fusulinid genera are restricted to the Tethyan areas, and the corresponding succession of conodont zones in their type sections have not been recognised yet.

Conveniently, Kungurian and Guadalupian sequences were well documented by the fine zonation of the fusulinids (Zhu & Zhang 1994) and the conodonts (Wang Z.-H. 1994) in South China. The successive appearance of the Kungurian and Guadalupian leading species of conodont zones can be intercorrelated one by one between the slope sequences in the Loudian Section of South China (Wang Z-H. 1994: text-fig. 1) and the type section of SW USA (Wardlaw 1996). As illustrated in Fig. 2, the base of the *N. exculptus* Zone is within the *Pamirina* Zone and therefore, the basal boundary of the Kungurian Series could be lower than that of the Bolorian Stage (Zhu & Zhang 1994). It was followed by the *Mesogodolella gujioensis–M. intermedia, M. idahoensis* and then *Jinogondolella nankingensis* in both sections. But, there is an interval with a dominance of a shallow water conodont fauna, such as *Sweetognathus subsymmetricus* and *Sw. hangzhongensis* between the *M. idahoensis* Zone and the *J. nankingensis* Zone. It remains an open question whether the *Sweetognathus subsymmetricus* Zone is a counterpart of the upper *M. idahoensis* Zone or the lower *J. nankingensis* Zone in SW USA. Presuming that the *Sw. subsymmetricus* Zone corresponds to the lower part of the type *J. nankingensis* Zone, the associated fusulinids will belong to the *Praesumatrina neoschwagerinoides* Zone, but are higher than the *Cancellina dutkevitchi* Zone of Kubergandinian. This is further supported by the fact that the lowest level of *J. nankingensis* is the *P. multiseptata* Zone in the Lower Yangtze areas.

In its type area, the lower part of the Roadian formation contains relatively primitive species of fusulinacean *Parafusulina* and species of the

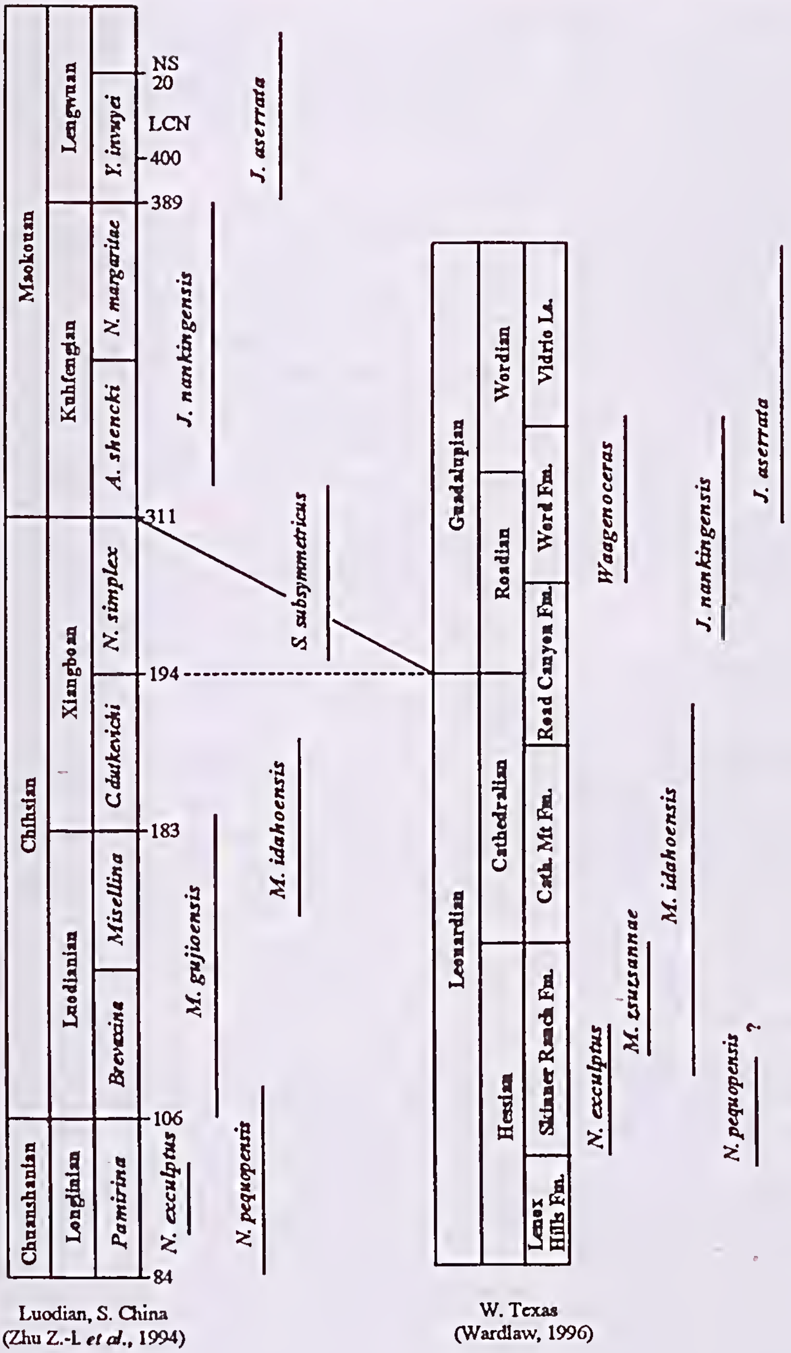

Fig. 2. Correlation of the successions of conodont zones in South China and SW USA.

ammonoid *Perrinites*, typical of the Leonardian. The succeeding middle and upper parts have advanced *Parafusulina* and the ammonoids *Waagenoceras*, typical of the Guadalupian Series. There is a major unconformity which separates the lower part from the rest parts of the Roadian

Formation (Ross 1995). Consequently, it cannot be excluded at present that the lowstand deposits with shallow water conodont fauna, i.e. the *Sweetognathus subsymmetricus* Zone in South China corresponds to the depositional gap within the Roadian Formation in West Texas.

Probably, the 'Roadian ammonoids' have to be redefined with the new definition of the Roadian Stage. The range-chart of Permian ammonoids in West Texas (Wardlaw 1996) shows that the most characterised ammonoid genus *Waagenoceras* commenced firstly from the Willis Ranch Formation, and the other ammonoid genera confined in the middle and upper parts of the Roadian Formation include *Paraceltites*, *Epithalassoceras*, *Tauroceras*, *Altudoceras*, *Texoceras*, etc. General surveys on the Permian ammonoids shows that *Daubichites* is widespread and is confined to the Roadian Stage (Nassichuk 1995; Zhou et al. 1997). In South China, *Daubichites* was reported from the Tingchiashan Formation, which is definitely the Kuhfengian in age (Zhao & Zheng 1977).

AN EVOLUTIONARY STASIS OR A LONG-TERM DEPOSITIONAL GAP?

The uppermost part of the Permian used to be referred to as a subseries, the Tatarian in the traditional standard succession. Based on Permian marine succession, this part has been formally named as the Lopingian (Huang 1932), the Dzhulfian (Furnish 1973), the Transcaucasian or the Yichangian (Waterhouse 1982) and others. The Lopingian Series has been proposed formally as an international standard for this series since recent studies prove that the Lopingian Series is not only a name proposed relatively early, but also represented by fully developed marine sequence with highly diverse faunas in South China (Jin et al. 1994). This series is subdivided into the Wuchiapingian and Changhsingian Stage, of which each contains two substages.

The proposed lower boundary of the Lopingian Series is delineated at the base of *Clarkina postbitteri* Zone of the Laibinian Substage in the Penglaitang Section, Laibin County of Guangxi. In Iran and the Transcaucasus, the succession of Laibinian is included in the *Araxilevis* Bed. A major unconformity corresponding with the pre-Lopingian global eustatic fall is not only marked by distinct lithological change but also by the occurrence of gypsiferous shale beds in the Jolfa Section of Iran. Before the *Araxilevis* fauna of the earliest Lopingian emerged, there was a long interval in which only a disaster fauna, the *Codonofusiella–Rechelina* fusulinid assemblage persisted. The Guadalupian–Lopingian transitional sequence is commonly composed of sediments of rather shallow and restricted environments and contains almost no macrofossils and hence, cannot be documented as a potential stratotype so far (Golshani et al. 1996).

For the Lopingian sequences without Tethyan marine fossils however, it is hardly possible to correlate them by standard Tethyan successions except of that the *Cyclolobus* fauna has been documented by ammonoids experts as a reliable mark of the Wuchiapingian (Dzhulfian) age. Though it has been suspected as 'Middle Permian' by others (Grant & Cooper 1973; Waterhouse 1976), increasing evidence from the Salt Range enable us to define the stratigraphic range of the *Cyclolobus* fauna as the Late Wuchiapingian and Changhsingian. This fauna occurs in the Kalabagh Member of the Wargal Formation with late Wuchiapingian conodont *Clarkina orientalis* and the overlying Chhidru Formation. The early Wuchiapingian conodont *Clarkina asymmetrica* was found from the underlying upper Wargal Formation but the specimens of that species was assigned to *Mesogondolella leveni* in previous work (Wardlaw & Pogue 1995).

The conodonts from peri-Pangean sequences of the late Permian generally show a low diversity of cool water faunas, and used to be dated as late Guadalupian in age, including the conodonts from the topmost Permian, regardless being of it succeeded by earliest Triassic ammonoid and conodont faunas. The gondolellids used to be referred to *Neogondolella phosphoriaensis* or *Neogondolella rosenkrantzi.* Wardlaw (1995) has considered these two species as synonymous, but recently found an evolutionary lineage from *N. phosphoriaensis* of the pre-Wordian to *N. rosenkrantzi* of the Lopingian despite that the morphological differentiation is trivial (Wardlaw 1997, pers. comm.).

In the Selong Section of southern Tibet, China, the conodonts from the *Waagenites* Bed, beneath the *Otoceras* Bed with *Hindeodus parvus*, comprise *Neogondolella* aff. *phosphoriaensis*, and *Clarkina* aff. *changxingensis* (Jin et al. 1996). Nearly identical conodonts from the Permian–Triassic boundary sequences were also found elsewhere, but none were dated as post-Wordian in age. Therefore, a depositional gap spanning the Capitanian to Changhsingian was suggested. The close relation between the conodont faunas below and above the 'Gap' indicates that it is most unlikely. It sounds more reasonable to refer the *Waagnites* Bed to the latest Lopingian.

Series	Stages	Biozons	Tethyan area			Peri-Pangea
		Substages	**Fusulinids**	**Conodonts**	**Ammonoids**	
Lopingian	Changhsingian	Meishanian	*Palaeofusulina sinensis*	*Clarkina meishanensis* *C. yini* *C. changxingensis*	*Rotodiscoceras* *Pseudotirolites-Pleuronodoceras*	*Clarkina* aff. *changxingensis* ↑
		Baoqingian	*Palaeofusulina minima-Gollowayinella meitiensis*	*C.wangi* *C. subcarinata*	*Pseudostiphenites-Tapashanites* *Paratirolites-Shevyrevites* *Iranites-Phisonites*	?
	Wuchiapingian	Laoshanian	*Nanlingella simplex-Codonofusiella kuangsiana*	*C. orientalis* *C. guangyuanensis* *C. leveni*	*Sanyangites* *Araxoceras-Konglingites* *Anderssonoceras-Prototoceras*	*Cyclolobus* spp.
		Laibinian		*C. asymmetrica* *C. dukouensis* *C. postbitteri*	*Roadoceras-Doulingoceras*	*Paramexicoceras addanense* *Mesogondolella rosenkrantzi*

Fig. 3. Correlation of Lopingian fossil zones in Tethyan areas and Pangean shelves.

The brachiopods and corals from the top part of the peri-Pangean sequences of the Permian usually show a pre-Lopingian aspect. Even the age of benthic faunas from the Kalabagh Member of the Wargal Formation and the Chiddru Formation were previously regarded as the Guadalupian which contain a significant amount of Tethyan forms (Grant & Cooper 1973). They have not been recognised previously as a distinct assemblage of younger age, probably because these fossil groups lack diagnostic forms of the Lopingian. The brachiopods from the Permian–Triassic boundary beds were often regarded as reworked associations of pre-Lopingian faunas although the taphonomic evidence do not support such an assumption. Similar faunas were found all over globe, both in Tethyan and the peri-Pangean sequences, including the Hogup Mountains of Utah, USA (Wardlaw & Mei 1997, pers. comm.). There is no question that these faunas represent the late survivors that somehow survived the earliest step of the end-Changhsingian catastrophe.

Long-standing interpretation has suggested an interruption in deposition of more than ten million years over vast peri-Pangean shelves, even though the physical evidence of regional truncation is not evident. We suggested that the conventional biostratigraphic estimation of the duration of a depositional gap between the Permian and the Triassic carbonate facies appears to be overly long, too widespread, and in need of re-evaluation. We interpret slow, yet generally continuous deposition across the P–T boundary, and an evolutionary stasis of marine faunas over peri-Pangean shelves.

NORTH–SOUTH CORRELATION OF THE PERMIAN

The north–south correlation of Permian chronostratigraphic successions has been a difficult problem for Permian biostratigraphers and especially so for the correlation of Permian successions above the Artinskian Stage because of the strong latitudinal differentiation of biogeographic realms. Recent progress in the isotopic age of the Permian in eastern Australia and the Urals may prompt researchers to rethink some long-held views about correlation between the middle and upper parts of the Permian in the Urals and Australia (Roberts 1991; Roberts et al. 1996; Chuvashov et al. 1996). New isotopic dating results from ash beds in the Guadalupian of SW USA and the Lopingian sequences of South China have made a time framework for the upper Permian possible.

Among isotopic age reported for eastern Australia, that of the bentonite within the Mulbring Siltstone is particularly interesting. It was dated as 264.1 ± 2.2 Ma. The Mulbring Siltstone is commonly referred to the Ufimian in the time scale of the Permian in Australia (Archbold et al. 1991). The regression reflected by sedimentation of conglomerate and sandstone of the underlying Muree Sandstone is regarded as a very important episode which may be coeval with the Middle Ufimian regression of the Northern Hemisphere (Chuvashov et al. 1996). The microfloras from the overlying Wittingham Coal Measure–the Tomago Coal Measure are assigned to the palynozones AAP4 and AAP5 of Price (in Draper et al. 1990), which are assumed to be, respectively, Ufimian and Kazanian–Dzhulfian in age. Based on the correlation mentioned above, an age of 264.1 ± 2.2 Ma is referred for the Ufimian Stage.

A magnetostratigraphic study locates the top of the Carboniferous–Permian Reverse Superchrone (CPRS) in the lower part of the Wittingham Coal Measure in Northwestern Sydney Basin (Theveniaut et al. 1994). Since the upper part of the succession of mixed polarity in the Wittingham Coal Measures is assigned to the interval Kazanian–Dzhulfian, a probable Ufimian age is given to the level corresponding with the top of the Carboniferous–Permian Reverse Superchrone (CPRS), or the Illawarra Reversal (IR).

Meanwhile, the magnetostratigraphic and isotopic age data automatically suggest an alternative correlation for the Mulbring Siltstone and the lower part of the Wittingham Coal Measure in eastern Australia, that is, Late Guadalupian or Early Tatarian age (Jin & Menning 1996). The Pb/U zircon age of 264.1 ± 2.2 Ma and the mixed polarised Wittingham Coal Measure might be reliable results. The IR has been well documented as a consistent level in the lower part of the Tatarian in the Urals. It also has been located in the Wargal Formation of Capitanian (the *Neoschwagerina margaritae* Zone) in the Salt Range (Haag & Heller 1991), the uppermost part of the Maokou Formation of the Capitanian (the *Yabeina* Zone) in South China (Heller et al. 1995). The age of 264.1 ± 2.2 Ma also suggests an assignment of Late Guadalupian since it agrees with the age of bentonites from the uppermost Wordian in the Guadalupe Mountains, that is 265.3 ± 0.2 Ma (Bowring et al. 1998).

Additional radiometric ages from eastern Australia, 272.2 ± 3.2 Ma for the base of the Kungurian (Chuvashov et al. 1996) may be reinterpreted as the Roadian Stage. The 'Kungurian' rocks in western Australia are characterised by occurrence of the species of *Daubichites*, *Agathiceras* and *Paragastrioceras*. These genera are usually regarded as the distinctive elements of Roadian ammonoid fauna in SW USA and other areas (Nassichuk 1995; Wardlaw 1996; Zhou et al. 1996). Shifting the Permian strata of Australian to a younger chronostratigraphic stage is further supported by the age 253.4 ± 3.2 Ma for the Kazanian bentonite bed in eastern Australia, since it is fairly close to the SHRIMP age of the Permian–Triassic boundary in the Meishan Section of South China, i.e. 251.2 ± 3.4 Ma (Claoué-Long et al. 1991).

The apparent discrepancy between the chronostratigraphic assignment of the isotopic age for Eastern Australia (Roberts 1991; Roberts et al. 1996; Chuvashov et al. 1996) and the possible alternative interpretation, as well as that of the IR to the Ufimian in eastern Australia (Theveniaut et al. 1994) and to the Late Guadalupian in other areas, resulted from the conventional North–South correlation of the Permian chronostratigraphic subdivisions. This correlation appears to be in need of major revision based on the reliable data of magnetostratigraphy and isotopic dating. Almost all Permian biota in eastern Australia cannot be used to correlate with type Russian Permian (Roberts et al. 1996). The ammonoids should be regarded as an exceptional group. However, the stratigraphic range of ammonoid faunas in Australia suggests an age younger than the conventional dating. The genus *Uraloceras* from eastern Australia used to be referred as the Artinskian in age but in the type area, the *Uraloceras federowi* fauna has been largely considered as the Kungurian (Chuvashov 1995). As mentioned in the preceding paragraph, the

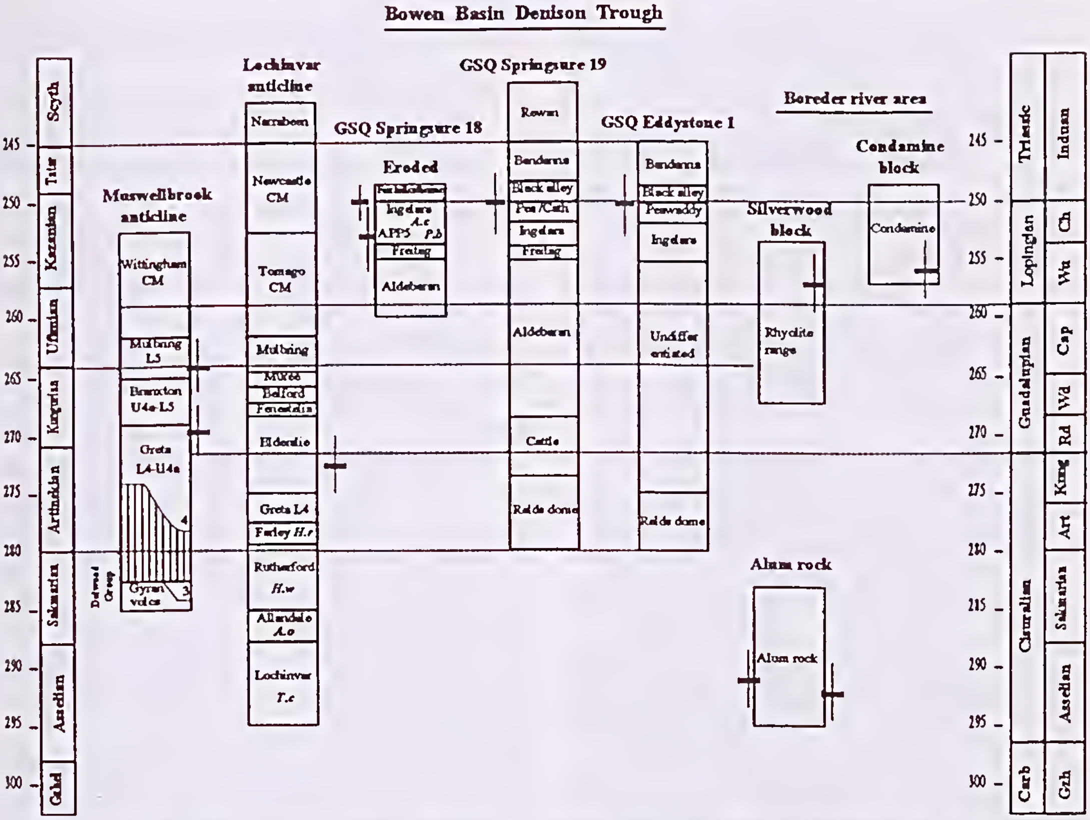

Fig. 4. Possible correlation of Permian sequences in eastern Australia in terms of isotopic age. The correlation chart between lithostratigraphic sequences and the traditional chronostratigraphic scheme are adopted from Roberts et al. (1995). The integrated chronostratigraphic scheme (Jin et al. 1997) on the right hand side suggests an assignment to younger stages. SHRIMP zircon dates indicated by solid horizontal line with error bars.

Daubichites fauna in western Australia is likely the Roadian rather than the Kungurian in age.

CONCLUSIONS

The existing disparities in correlation between key levels of Permian sequences imply that we are confronted with a strong challenge in achieving agreement. It also means a global correlation of high resolution is urgently demanded. As an interpretation about time-relations for the Permian world wide, correlation is permitted variation according to various authors. However, as has been emphasised, Permian correlation must continuously evolve in keeping with the growth of stratigraphic data and, more substantial contributions in improving the international correlation are expected.

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